

REMARKS

Claims 1-4 and 6-15 are pending. By this Amendment, claims 1 and 6 are amended to recite features supported in the specification, for example, at page 8, lines 6-19. No new matter is added by any of these amendments.

Applicant appreciates the courtesies extended to Applicant's representative by Examiner Abdulsalam during the May 17, 2005 interview. In accordance with MPEP §713.04, the points discussed during the interview are incorporated in the remarks below and constitute Applicant's record of the interview.

Reconsideration based on the following remarks is respectfully requested.

I. Amendment Entry with Request for Continued Examination

Entry of this amendment is proper under 37 CFR §1.114 because this Submission is filed in conjunction with a Request for Continued Examination.

II. The Claims Satisfy the Requirements under 35 U.S.C. §112, second paragraph

The Final Office Action rejects claims 1-4 and 6-15 under 35 U.S.C. §112, second paragraph, as being indefinite. Claims 1 and 6, as amended, obviate this rejection, as agreed during the interview. Withdrawal of the rejection under 35 U.S.C. §112, second paragraph is respectfully requested.

III. Claims 1-4 and 6-15 Define Patentable Subject Matter

The Final Office Action rejects claims 1-4 and 6-15 under 35 U.S.C. §103(a) over U.S. Patent 5,774,105 to Yamamoto *et al.* (incorrectly identified in the Final Office Action as Ishizawa and hereinafter "Yamamoto") in view of U.S. Patent 6,411,282 to Ishizawa *et al.* (hereinafter "Ishizawa") and U.S. Patent 6,304,431 to Kim. This rejection is respectfully traversed. As agreed during the interview Yamamoto, Ishizawa and Kim, alone or in combination, do not teach or suggest an information display system including the features recited in claim 1, and similarly recited in claim 6. The claims as presented herein differ slightly from those discussed during the interview. Applicant submits that the claims nonetheless distinguish over the applied references.

During the interview, Examiner Abdulsalam raised inquiries regarding the operability of the display devices after power cutoff. As discussed during the interview, the specification

at page 8, lines 6-19, states that each display device can be one of a ferroelectric liquid-crystal display device, a cholesteric liquid-crystal display device and an electrophoretic display device. Literature is attached to provide additional background on these technologies.

For at least these reasons, Applicant respectfully asserts that the independent claims are now patentable over the applied references. The dependent claims are likewise patentable over the applied references for at least the reasons discussed as well as for the additional features they recite. Consequently, all the claims are in condition for allowance. Thus, Applicant respectfully requests that the rejection under 35 U.S.C. §103 be withdrawn.

IV. Conclusion

In view of the foregoing, Applicant respectfully submits that this application is in condition for allowance. Favorable consideration and prompt allowance are earnestly solicited. Should the Examiner believe that anything further is desirable in order to place this application in even better condition for allowance, the Examiner is invited to contact Applicant's undersigned representative at the telephone number listed below.

Respectfully submitted,



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JAO:GWT/gwt

Attachments:

Request for Continued Examination

"Ferroelectric Liquid Crystal Devices", <http://www.lci.kent.edu/boslab/projects/flc/>

"Polymer Stabilized Cholesteric Liquid Crystals", <http://plc.cwru.edu/tutorial/enhanced/files/pslc/psclc/psclc.htm>

"14-1: Passive Matrix Addressing of Electrophoretic Image Display", T. Bert *et al.*, http://www.elis.ugent.be/ELISgroups/tfeg/public/eurodisplay2002_s14-1.pdf

Date: June 23, 2005

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Ferroelectric Liquid Crystal Devices

Unlike their nematic cousins, ferroelectric liquid crystals exhibit a net dipole over the bulk of the material. Because of their electrical polarization properties, ferroelectric liquid crystals may switch very quickly under a DC field. Ferroelectrics are chiral smectic C devices, meaning that they have a layered structure with the molecules at some angle (the "cone angle") away from the layer normal, and that there is some inherent twist in the structure. That is, in an unconstrained system, the azimuthal direction in which the molecules tilt away from the layer normal will differ slightly from one layer to the next.

The most common configuration for a ferroelectric liquid crystal device is the Surface Stabilized Ferroelectric Liquid Crystal (SSFLC) configuration, in which the natural twist of the material is suppressed by the surface conditions. Such devices are commonly about 1 or 2 microns thick, and have a parallel rubbing configuration (figure 1). The first picture in this figure shows the smectic layer structure in the smectic A phase through which the liquid crystal passes as the display is cooled from isotropic. The second picture shows the chevron-layer structure that appears in such devices as the material forms the smectic C phase. As the molecules tip away from the layer normal on passage from A to C, the layers contract somewhat, forcing the chevron structure to form. The chevron structure allows the layer spacing to decrease while maintaining a fixed number of layers. As will be discussed in more detail below, the direction in which the apex of the chevron points is related to the pretilt direction of the surface, which is determined by the direction of rubbing.

When a DC voltage is applied across the two display substrates, the molecules rotate around the cone so that in the center region of the chevron, the direction the molecules are pointing changes in the plane of the cell by about 45° . Thus, the ferroelectric may act as a linear retarder whose direction can be switched very quickly from being along the polarization direction of incident light to being at 45° from the polarization direction of the light. If the material retards the light by a half wave, then the state of the light on reaching the exit polarizer may be changed from 0° to 90° , allowing for black-and white operation.

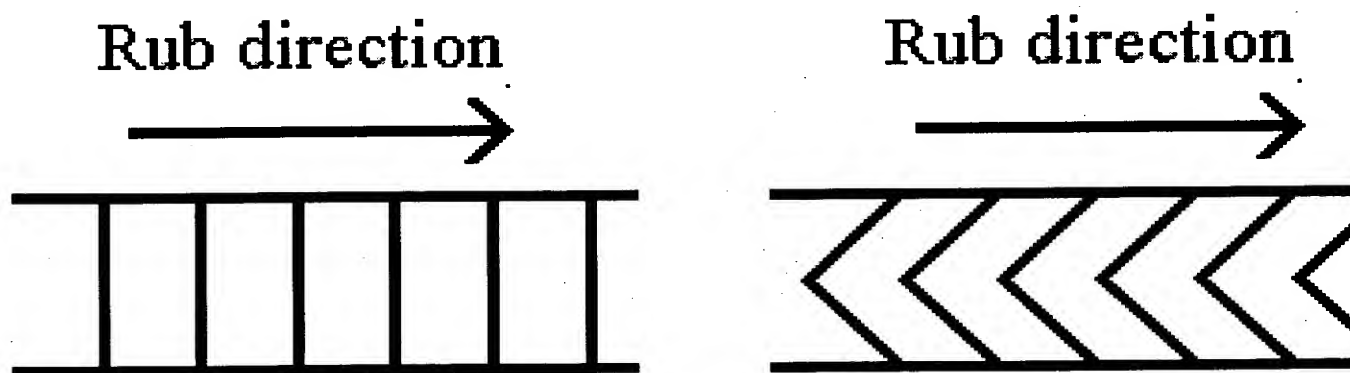


Figure 1. Layer structure in an SSFLC device.

Although they are geometrically very closely related, the cone angle to which the molecules tip away from the layer normal is not always equal to the chevron angle, defined as the angle to which the layers tip away from the cell normal direction. The relative values of the cone angle, the chevron angle, and the pretilt angle determine if the chevron apex is geometrically allowed to point along the rub direction (a "C2" chevron), opposite the rub direction (a "C1" chevron), or both. The details of the geometry are shown in figure 2.

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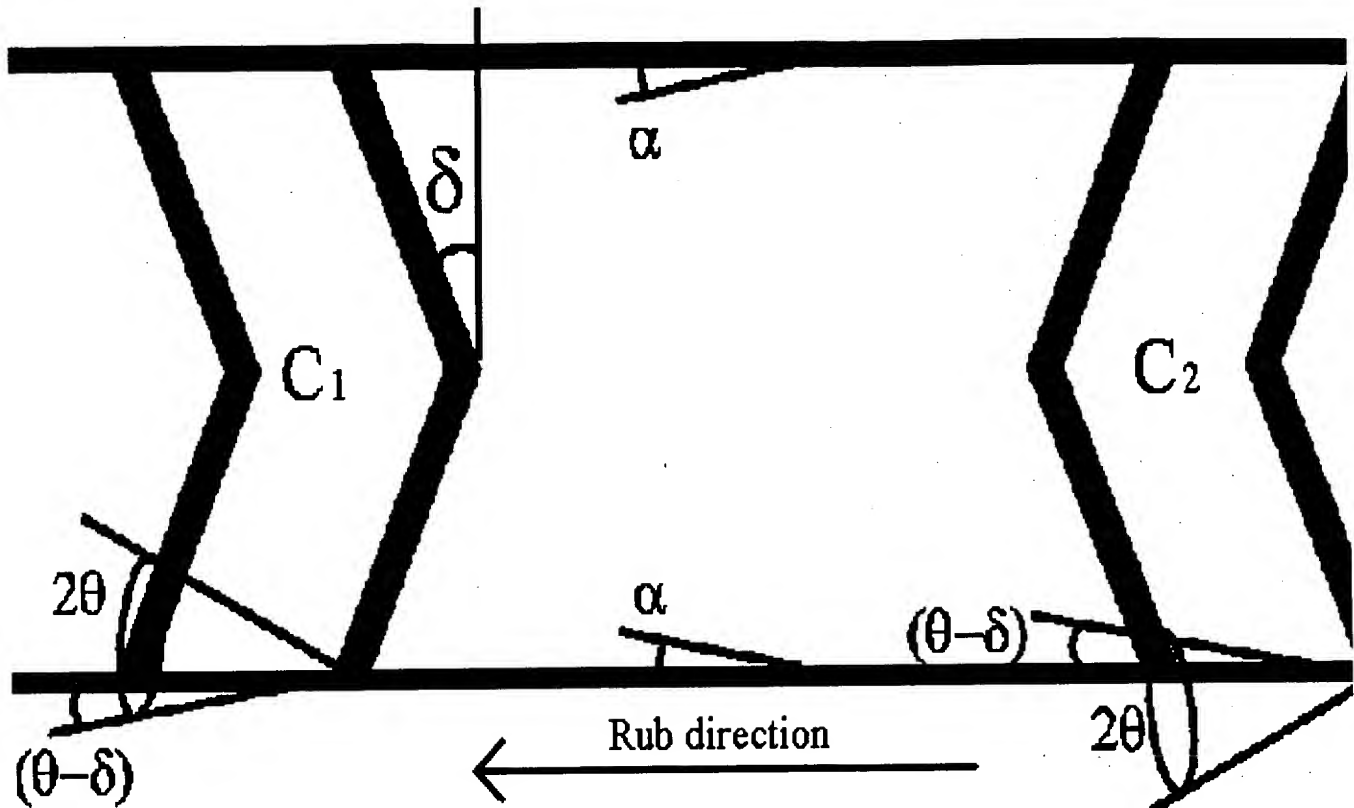


Figure 2. Details of the geometry of various chevron structures in a ferroelectric LCD.

Note the cone drawn along the lower surface for each chevron type. This cone represents the set of all directions that are tipped exactly θ (the cone angle) away from the smectic layer direction at the surface. In order for the chevron to be compatible with the given pretilt (α , shown in the center of the figure), the cone must intersect with the pretilt at some point. Otherwise, the surface conditions cannot be met without significant distortion of the chevron. The chevron angle in this figure is designated by δ . As can be seen from the geometry of figure 2, the conditions for the different chevron types to be allowed is as follows:

$$C1: 0 < \alpha < \theta + \delta$$

$$C2: 0 < \alpha < \theta - \delta$$

For display devices, it is desired that only one type of chevron be present, because the presence of both types of chevrons in a display results in the formation of zig-zag defects, which appear at the intersection of domains with different chevron types. The two types of zig-zag defects are shown in Fig. 3.

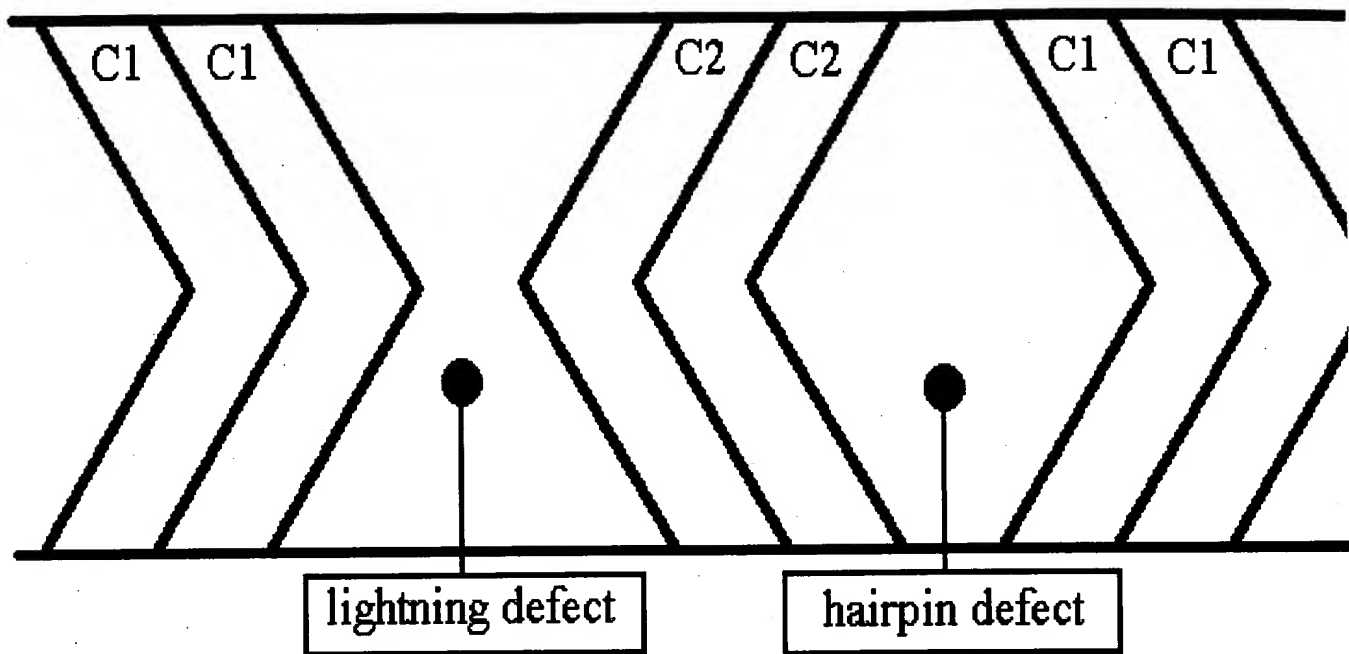


Figure 3. Formation of zig-zag defects.

A microscope photograph of zig-zag defects viewed between crossed polarizers is shown in figure 4. The presence of zig-zag defects in a display pixel can drastically reduce the contrast of the pixel.

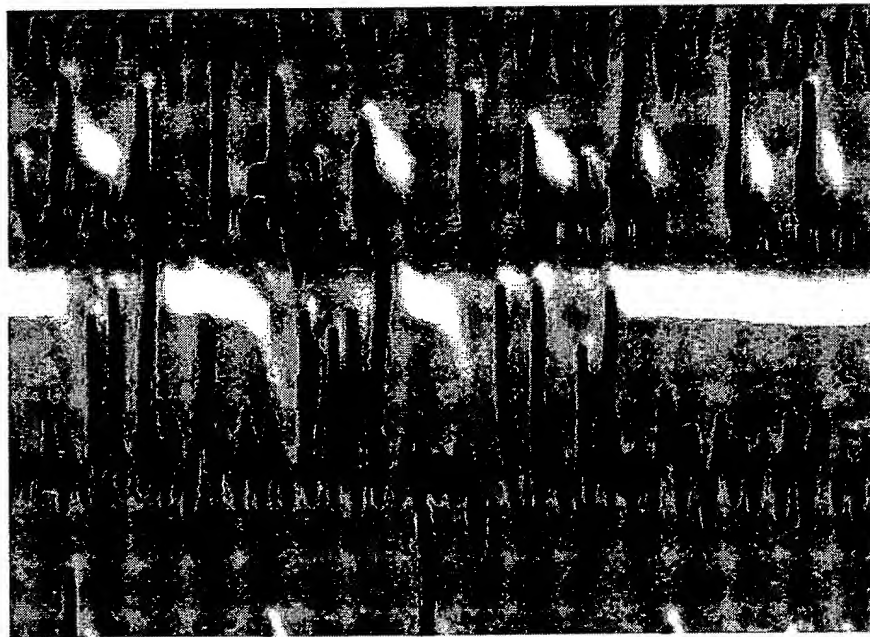


Figure 4. Zig-zag defects viewed between crossed polarizers.

Based on the understanding of chevron allowance conditions, Tsuboyama and other researchers at Canon determined that a high pretilt would be effective in eliminating the C2 structure, thus allowing for a uniform, high contrast device.

Unfortunately, high pretilt polyimides are not commonly available like low pretilt polyimides are. Thus, a further understanding of the parameters governing zig-zag defects was necessary. We decided to focus on surface topography as a possible initiator of zig-zag defects. A diagram of how an imperfect surface can effect the pretilt at a surface is shown in Fig. 5.

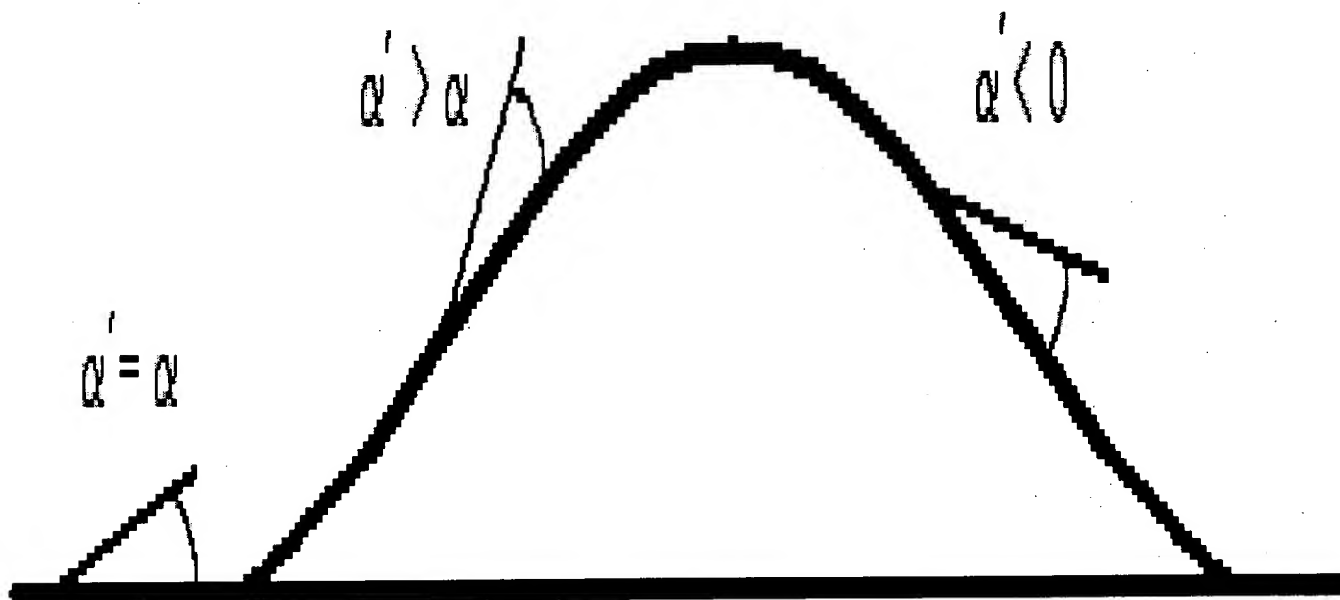


Figure 5. A ridge on a surface resulting in changes to the pretilt conditions. The pretilt condition on the right is effectively reversed.

In this study, we investigated the effects of surface topography on the formation of zigzag defects in SSFLC devices. Our concern was that a rough surface would be likely to reverse the pretilt direction in small areas of the surface, thus resulting in interspersed regions of chevrons pointing in opposite directions, and therefore in high densities of defects. We used an AFM to determine surface topography, and quantified the defect density through microphotography and image analysis. The results of this study may be found in the following references:

Effects of Surface Topography on formation of defects in SmC* devices explained using an alternative chevron description. P. Watson, P.J. Bos, J. Pirs. *Phys. Rev. E*, **56**, 4, (1997). (Rapid Communication.).[PDF] [DjVu]

Effects of Surface Topography on Formation of Zig-Zag Defects in SSFLC Devices, P. Watson, P.J. Bos, J. Pirs. *Society of Information Display International Symposium Digest of Technical Papers*, p 743 (1997).

Effects of surface topography on formation of zig-zag defects in SSFLC devices, P. Watson, P.J. Bos, J. Pirs, ALCOM Technical Report VIII, p30 (1996)

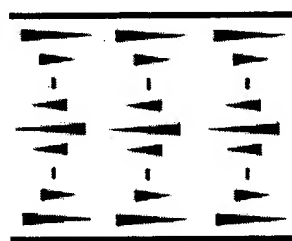
An observation of the effect of the surface topography on the defect density in SmC* devices. J. Pirs, S. Kralj, S. Pirs, B. Marin, P. Watson, C. Hoke, P. Bos. 16th ILCC D1P.29 (1996)

Polymer Stabilized Cholesteric Liquid Crystals

Cholesteric Liquid Crystals have many applications as electro-optic materials in thin film devices in much the same way as nematic liquid crystals do. The presence of a polymer network formed at low polymer concentrations provides similar advantages in enhancing the stability of the structure, aiding in the return of the liquid crystal *director* orientation to the desired stable configuration, reducing the switching time, and helping to determine and maintain the poly-domain size.

After introducing cholesteric textures and some of their optical properties (in the regime where the pitch of cholesteric helix is in the range of visible wavelengths of light, not the infrared), we will consider some representative devices.

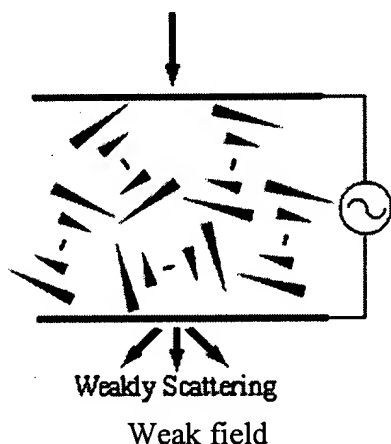
Planar Cholesteric Texture



No field

Just as in the case of the *nematic mesophase*, cholesterics placed between two parallel surface treated plates form a planar *homogeneous* texture in the absence of an external electric field. The axis of the helix formed by the director lies normal to the plates, with the director of the molecules adjacent to the plates parallel to the rubbing direction. In the figure, the wedge-shaped symbols represent layers of planes and indicate their average director orientation.

Focal Conic Texture



Weakly Scattering

Weak field

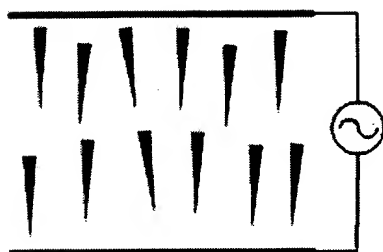
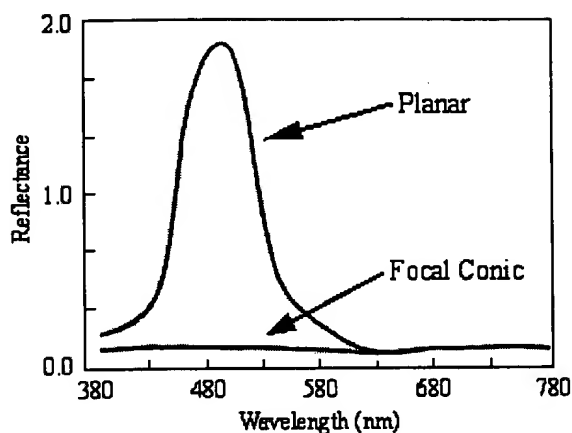
If a small electric field is applied normal to the plates in the example above, the molecules experience a torque which, as we have seen in the nematic mesophase, tends to align the director normal to the plates, eventually producing the *homeotropic texture*. However in the cholesteric mesophase, due to interactions with adjacent molecules and with anchoring effects near the plates, a focal conic texture is formed, as illustrated.

A random distribution of helical axes is characteristic of the focal conic texture. In this case, incident light is weakly scattered in all directions.

Selective Reflection

In the planar texture, cholesteric liquid crystals display selective reflection. The reflected intensity plot over the visible spectrum shown below illustrates this, with maximum reflection occurring at a wavelength equal to the pitch, which may be pre-selected by choices of materials. This represents the reflection of one handedness of circularly polarized light due to periodic variations of the index of refraction of the material. The other handedness is transmitted through the cholesteric material.

Please note, the focal conic texture scatters light of all frequencies.

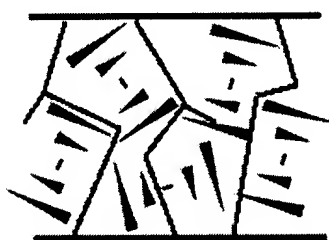


Strong field

If the electric field is increased above a threshold value, the helical structure of the focal conic texture is untwisted and the director becomes perpendicular to the plates, forming the homeotropic texture. In this state, shown in the diagram, the material is transparent to incident light.

Polymer Network

Polymer networks are formed in cholesterics during the initial stages of film preparation by combining a small quantity of reactive monomer and photoinitiator with the cholesteric liquid crystal molecules, just as in the case of the nematics. In fact, the process can be identical, except that a small amount of chiral dopant is added to produce the desired cholesteric pitch. After the desired texture is established through the combination of surface preparations and applied field, ultraviolet light is used to photopolymerize the sample. The morphology of the resulting polymer network mimics the textures of ordinary cholesteric mesophases. Such a network is schematically illustrated by the blue lines in the figure below (shown in the focal conic texture). These polymer stabilized cholesteric textures are sometimes referred to by the acronym PSCT.



In the presence of polymer networks, the liquid crystal material is broken up into small domains referred to as polydomains which do not necessarily coincide with the boundaries between regions of common helicity in the focal conic texture. Even in the planar texture, polydomains have slightly different orientations relative to each other, as noted earlier.

Studies of the network formed in cholesterics have been reported by several groups including the ALCOM researchers mentioned in the discussion of stabilization of nematics (*Rajaram, 1996 and Dierking, 1997*). Just as in the case of nematics, after removal of the liquid crystal material, SEM and special optical microscopy have shown a fiber-like anisotropic network whose morphology has been influenced by the presence of the liquid crystal, including evidence of the helical cholesteric texture. In turn, the network influences the structure of the focal conic state and stabilizes initial states. Factors controlling morphology, such as liquid crystal texture, monomer concentration, photopolymerization

temperature, UV intensity and exposure time have been explored and discussed in those references.



14-1: Passive Matrix Addressing of Electrophoretic Image Display

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Abstract

This paper presents a novel technique for passive matrix addressing of electrophoretic displays. The addressing scheme is successfully applied in a working demonstrator with 5x7 pixels. To our knowledge, this is the first time a working electrophoretic display with passive matrix addressing is presented.

1. Introduction

There is an increasing interest in bi-stable, reflective displays technologies such as Electrophoretic Image Display (EPID). Low power consumption, high contrast in outdoor environment and the potential combination with flexible substrates make EPID especially suited for large area applications such as signs and billboards for advertising purposes.

The electrophoretic image displays that are being marketed to date, are addressed using direct drive, which means that every pixel is directly connected to a dedicated output of the driving electronics. However, as a result of the rapidly increasing pixel count and pixel density, it becomes mandatory to multiplex the driving signals somehow. In liquid crystal display technologies, this is normally done using active or passive matrix addressing. Active matrix addressing implies that an electronic switch (usually a Thin-Film Transistor or TFT) is incorporated at every pixel location. This is not needed for passive matrix addressing, which relies on the intrinsic switching capability of the display medium due to a voltage threshold in its electro-optical response curve. Due to its complexity, the active matrix technology has always been more expensive than the much simpler passive matrix technology.

The use of active matrix addressing in flexible large area applications however, is still in an early development phase, and far from obvious, although several research groups are working in this direction [1,2,3].

On the other hand, the backplane of passive matrix addressed electrophoretic display can be as simple as a PET substrate with a simple ITO pattern.

Passive matrix addressing of electrophoretic displays would therefore be a very attractive alternative, leading to a reduction in development time, production complexity and manufacturing cost.

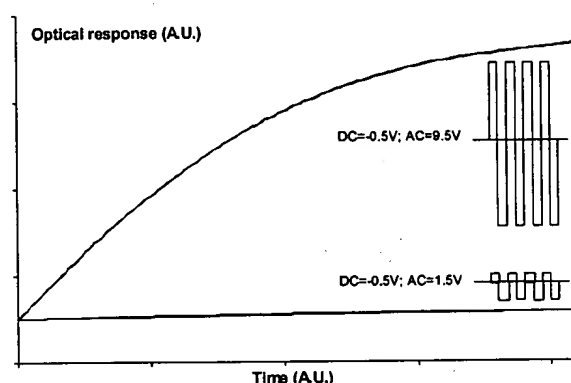


Figure 1 Optical response as function of time for two different addressing waveforms with the same DC component

2. Problem definition and prior art

It is generally believed that, due to the lack of a threshold voltage, passive matrix addressing is not compatible with electrophoretic image displays.

In the past, matrix addressing of electrophoretic displays was indeed only demonstrated using a complicated triode design in the display [4]. Unfortunately, this approach adds to the cost and even sacrifices the possibility of creating a flexible display.

Although a threshold voltage is indeed not observed in the electrophoretic electro-optical effect, the switching characteristic is certainly not a linear function of the applied voltage. Because the distribution of the electric field depends on the position and movement of the charged pigments, the non-linearity increases even more.

Furthermore, the dynamics of an electrophoretic pixel is quite peculiar and is characterized by a prominent memory effect.

This paper describes how we have succeeded in employing the non-linearity and the typical dynamic behaviour of the electrophoretic effect to design a passive matrix addressing scheme.

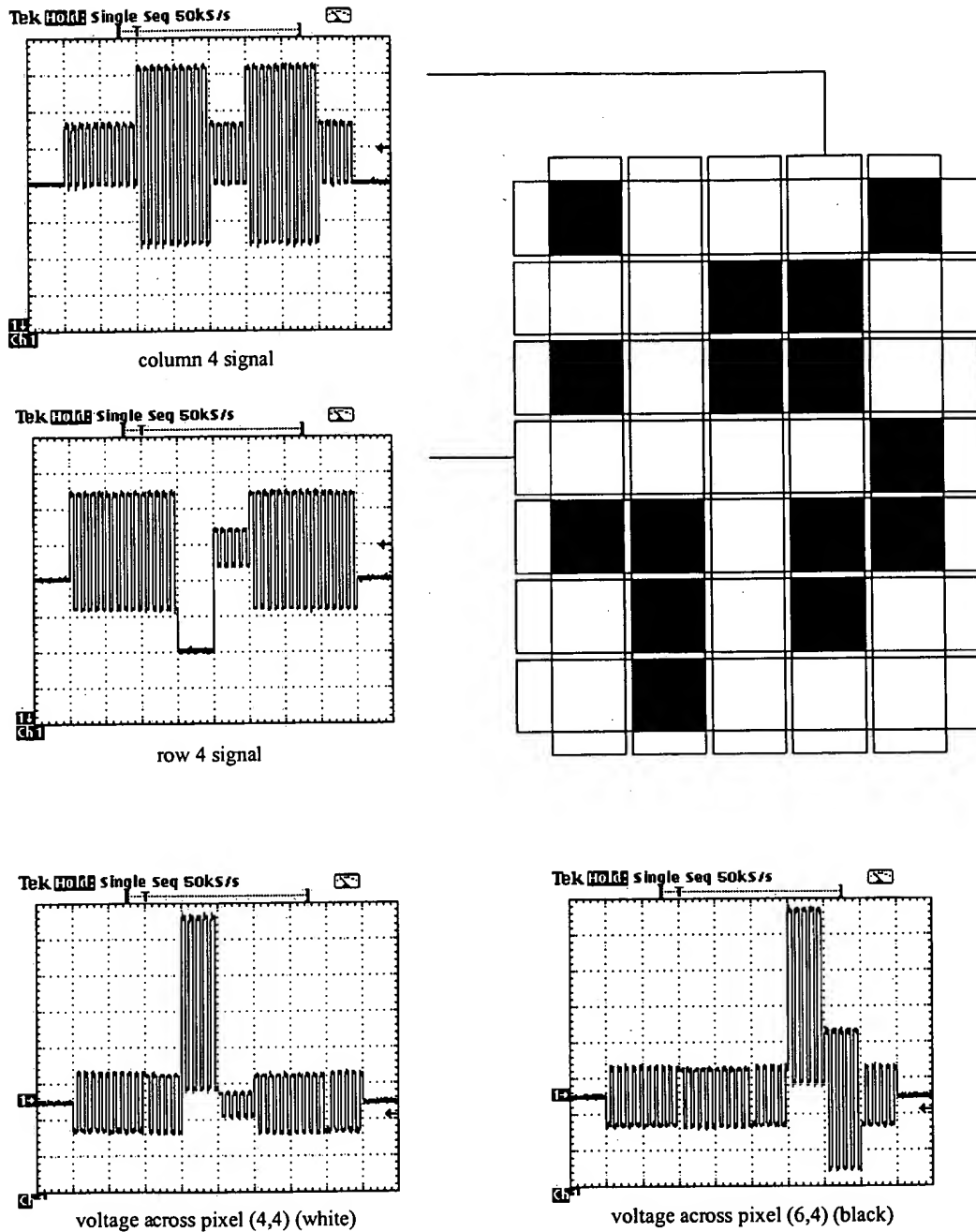


Figure 2 Passive matrix driving scheme: row and column signals and resulting voltage across a pixel that switches to white and a pixel that switches to black

3. Experimental data gathering

Using a test set-up that monitors the reflectivity of the display, we investigated the switching behaviour of electrophoretic cells. These cells show a strong memory effect, that complicates the driving schemes.

We focused on the response to periodic square waves with different amplitudes, frequencies and DC components. We found that the reaction speed of the cell to a modest DC component can dramatically be increased by the addition of a sufficiently strong AC component. This behaviour is illustrated in Figure 1.

We also found that a signal with a moderate AC component but without a DC component does not significantly influence the reflectivity of the cell.

The observed behaviour is consistent with the assumption that the DC component provides the driving force for the pigments to migrate from one side to the other, while the AC component provides the energy to overcome the forces that act on the particles at the electrode.

4. Passive matrix addressing scheme

Figure 2 shows a passive matrix addressing scheme that is based on these findings. The addressing consists of 3 consecutive phases: preparation, selection and rest. The image is written from top to bottom, which means that first, all rows except the first one, are in the "resting" phase and the first row is in the "preparation" phase. After one row time, the second row enters the preparation phase and the first row is in the "selection" phase. To the column electrodes, signals are applied that correspond with the desired state (black or white) of the pixels in the selected (first) row. After another row time, the third row enters the preparation phase, the second row enters the selection phase and the first row is again in the resting phase. This process continues until all rows have been written in.

We will now discuss the different phases in some more detail:

4.1 Preparation phase

During the preparation phase, a complete row of pixels is switched to the reflective state by applying the combination of a high positive DC voltage and an AC voltage. This is accomplished by biasing the corresponding row electrode with a sufficiently high negative DC voltage. Although the exact waveform seen by a pixel in the preparation row depends on the signal on the corresponding column, the end result is always the same: the pixel turns to white.

4.2 Selection phase

During the subsequent selection phase, the same row of pixels experiences a small negative DC component, combined with an AC component that depends on the column driver output. If this AC component is weak, the pixel stays reflective; if the AC component is strong, the pixel switches to black, corresponding with the behaviour shown in Figure 1. This is accomplished in practice by applying a small AC signal with a modest positive DC bias to the selected row and AC signals with either a low or a high amplitude to the columns.

4.3 Resting phase

During the resting phase, the pixels experience a modest AC signal without DC component, which leaves them unchanged.

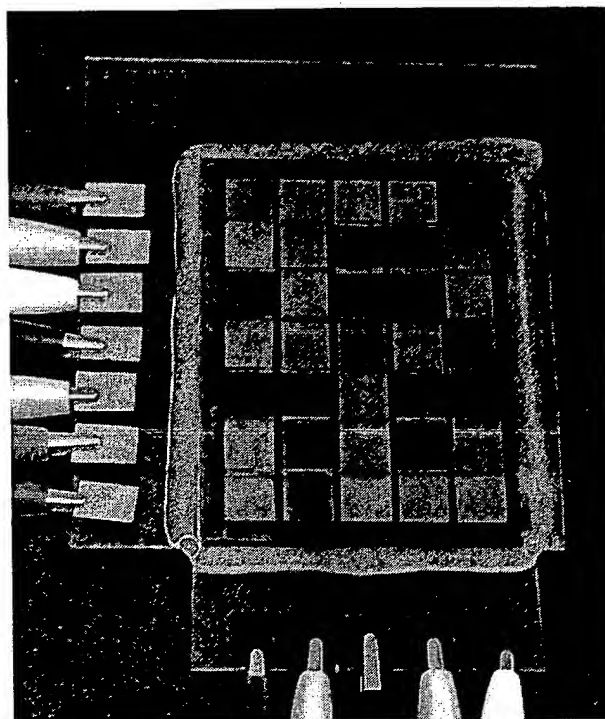


Figure 3 Photograph of a 5x7 matrix display, demonstrating the passive matrix driving of an electrophoretic display

This is accomplished by applying to the "resting" rows an AC signal with the same frequency and phase as the column signals and whose amplitude is the mean value of the low and the high amplitudes of the column signals. Hence the amplitude of the resulting AC waveform experienced by the resting pixels does not depend on the data written to the selected row.

5. Implementation

To prove this principle of passive matrix addressing, we constructed a 5x7 electrophoretic image display with a blue dye and a yellow pigment. The top and bottom electrodes are patterned in rows and columns respectively, each pixel being approximately 1 cm² in size.

In order to apply the desired waveforms to the row and column electrodes, we used a driving circuit based on a versatile high-voltage low-power driver IC that was originally developed for cholesteric texture LCD addressing [5].

A photograph of a working passive matrix electrophoretic display is shown in figure 3.

6. Conclusion

This paper presents a novel technique for passive matrix addressing of electrophoretic displays. The lack of a threshold voltage, generally considered necessary for passive matrix addressing, is circumvented by exploiting the unique dynamic

behaviour of electrophoretic mixtures under a combination of AC and DC driving forces.

In addition, we present a working device demonstrating the application of the addressing scheme to a display of 5x7 pixels.

To our knowledge, this is the first working electrophoretic image display ever presented that is driven using passive matrix addressing.

The authors are convinced that the availability of passive matrix addressing of electrophoretic displays is an important step forward towards achieving a low cost large area flexible display technology.

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8. References

- [1] T. Kawase, H. Sirringhaus, R.H. Friend, T. Shimoda, "All-Polymer Thin Film Transistors Fabricated by High-Resolution Ink-jet Printing", in *SID01 Tech. Dig.*, pp. 40-43, 2001.
- [2] Y Chen, K. Denis, P. Kazlas, P. Drzaic, "A Comfortable Electronic Ink Display Using a Foil-based a-Si TFT Array", in *SID01 Tech. Dig.*, pp. 157-159, 2001.
- [3] K. Amundson, J. Ewing, P. Kazlas, R. McCarthy, J.D. Albert, R. Zehner, P. Drzaic, J. Rogers, Z. Bao, K. Baldwin, "Flexible, Active-Matrix Display Constructed Using a Microencapsulated Electrophoretic Material and an Organic-Semiconductor-Based Backplane", in *SID01 Tech. Dig.*, pp. 160-163, 2001.
- [4] Electrophoretic Display Panel with Internal Mesh Background Screen, US Patent 5,276,438 January 4, 1994.
- [5] J. Doutrelaigne, H. De Smet, and A. Van Calster, "A versatile micropower high-voltage flat-panel display driver in a 100V 0.7mm CMOS Intelligent Interface Technology", *IEEE Journal of Solid-State Circuits*, vol. 36, no. 12, pp. 2039-2048, 2001.